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ABSTRACT

This study compares the effectiveness of three types of computer graphics display for computer-assisted instruction in (1) low level (boxed alphanumerics and schematics), (2) medium level (line drawings), and (3) high level (line drawings plus animations). Three groups of 30 enlisted personnel at the Engineering School and the Defense Mapping School, Fort Belvoir, Virginia, studied a computer-assisted instructional lesson on the psychophysiology of audition. Upon lesson completion, retention of four knowledge categories addressed in the CAI lesson were tested. Groups did not differ in their performance on the final retention tests or in lesson completion time. Findings indicate that the addition of more realistic and sophisticated graphics displays in a CAI lesson do not insure an increase in instructional effectiveness but point out the need to determine principles and guidelines for the use of graphics in computer-based training. (Author)

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Technical Paper 359

THE INSTRUCTIONAL EFFECTIVENESS OF THREE LEVELS OF GRAPHICS DISPLAYS FOR COMPUTER-ASSISTED INSTRUCTION

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To date there is little evidence to support the widespread belief of educators and trainers that the use of visual displays enhances instructional effectiveness. This lack of supporting data is critical when computer-based education systems are considered training delivery vehicles; systems capable of providing sophisticated graphics displays are costly. The purpose of this experiment was to obtain data comparing the instructional effectiveness of

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three types of graphics displays for computer-assisted instruction (CAI). Three groups of subjects each studied one of three versions of a CAI lesson on the psychophysiology of audition. The text of the lesson was identical for all versions; the type of graphics used in the lesson was different for each group. No control group was used. Graphics were either low level (schematic representations and boxed alphanumerics), medium level (line drawings), or high level (animations plus line drawings). After completing the lesson, all subjects were tested for retention of four knowledge categories addressed in the lesson: acquisition and use of principles, identification of structures, definitions and use of terminology, and memory of specific facts. Results indicated that the type of graphics used during the CAI lesson did not affect lesson completion time or final performance on the retention tests.

Researchers in computer-assisted instruction and computer graphics are the intended audience for this report.

FOREWORD

The Educational Technology and Simulation Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) performs research and development in areas of educational technology with applicability to military training. Of special interest is research in the area of large-scale computer-based instructional systems. Development and implementation of such systems are seen as a solution to such current Army training problems as a shortage of qualified instructor personnel, a student population of widely varying abilities, and increased training costs.

Technological advances in computer technology now make it possible to use sophisticated graphics techniques in the instructional process. Although it has been assumed that the use of such techniques will improve training effectiveness, scientific evidence does not consistently support this viewpoint. This Technical Paper reports the results of the first phase of an in-house research and exploratory project investigating the effectiveness of instructional graphics in computer-based instructional systems.

The effort was initiated in response to the requirements of Army Project 2Q763731A762, "Computer Administered Instruction," FY 1975 Work Program, and was continued under Project 2Q763731A771, "System Embedded Training Development," FY 1978 Work Program.

Dr. Bruce W. Knerr and Specialist 5 Peggy McLintock contributed to the development of instructional materials used in the experiment. Personnel at the Learning Resource Center, Dr. Everett Rompf, and Mr. Jack Ainsworth, all of the Engineer School, Fort Belvoir, Va., assisted in providing the facilities and the personnel required to conduct the experiment.

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

THE INSTRUCTIONAL EFFECTIVENESS OF THREE LEVELS OF GRAPHICS DISPLAYS FOR COMPUTER-ASSISTED INSTRUCTION

BRIEF

Requirement:

To compare the instructional effectiveness of three different types of computer graphics for computer-assisted instruction (CAI).

Procedure:

. Three groups of 30 enlisted personnel studied a CAI lesson on the psychophysiology of audition. Three versions of the lesson were developed; each version differed only in the type of graphics used. Graphics were either low level (boxed alphanumerics and schematics), medium level (line drawings), or high level (line drawings plus animations). Upon lesson completion, retention of four knowledge categories addressed in the CAI lesson was tested.

Findings:

. Groups did not differ in their performance on the final retention tests or in lesson completion time. Performance was, however, related to General Technical (GT) score.

Utilization of Findings:

The addition of more realistic and sophisticated graphics displays to a CAI lesson does not insure an increase in instructional effectiveness. A need exists to determine principles and guidelines for the use of graphics in computer-based training.

THE INSTRUCTIONAL EFFECTIVENESS OF THREE LEVELS OF GRAPHICS DISPLAYS FOR COMPUTER-ASSISTED INSTRUCTION

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THE INSTRUCTIONAL EFFECTIVENESS OF THREE LEVELS OF GRAPHICS DISPLAYS FOR COMPUTER-ASSISTED INSTRUCTION

INTRODUCTION

The use of computers for education and training has increased within the past few years in military, industrial, and academic settings. Although much of this activity reflects the use of computers for the management of instruction, a substantial portion of this activity has also been directed toward computer-assisted instruction (CAI). Major obstacles to the implementation of computer-based education include the initial hardware/software costs and the follow-on cost of courseware development. In the case of CAI, both cost factors are greatly increased by the addition of sophisticated instructional capabilities.

There has been little systematic research on characteristics of CAI that are thought to optimize learning, even though it is precisely these instructional capabilities that contribute to much of the cost involved in CAI. For example, because educators often assume that there is an intrinsic instructional value in the use of graphics to supplement aural and textual presentations, graphics displays are seen as a desirable feature in CAI curriculum development. Thus, computer graphics capabilities, despite the additional procurement cost, are often an important factor in the design and selection of a CAI system. Furthermore, including graphics displays in a CAI lesson increases lesson development time and hence increases the cost of courseware.

A recent ARI review of the literature on the use of graphics in non-CAI instruction (Moore & Nawrocki, 1978) concluded that there is little empirical evidence to support a belief in the effectiveness of graphics:

> First, it is clear that the addition of graphic instructional material does not guarantee an increase in instructional effectiveness.... The second major conclusion is while there do appear to be conditions in which graphics may be an important adjunct to the instructional process, there is currently no systematic means for identifying these conditions.

The literature review did suggest, however, that a systematic research program would best be directed toward determining computer graphics effectiveness as a function of the type of graphics employed as well as of subject matter, learner task, and learner characteristics. The research reported here is the first in a series of experiments designed to explore the instructional effectiveness of computer graphics.

The main purpose of this experiment was to obtain data comparing the instructional effectiveness of several levels of computer graphics and to explore the interaction effects of levels of graphics with identifiable learner aptitudes and tasks. King (1975) investigated the instructional effects of computer graphics in teaching the sine-ratio concept and found no differences on a final test in the performance of groups receiving (a) CAI text only, (b) CAI text plus animated graphics, or (c) CAI text plus still graphics.

The present experiment manipulated three different levels of computer graphics: high (animations plus line drawings), medium (line drawings only), and low (schematic representations and boxed alphanumerics). Three versions of the CAI lesson on the psychophysiology of audition were developed. Each version differed only in the level of graphics used.

Psychophysiological lesson material was selected because of its potential for graphic manipulation and because the idea that graphics are necessary to teach this material effectively had much face validity. Four types of performance tests were administered to all subjects: (a) acquisition and use of principles, (b) identification of structures, (c) definitions and use of terminology, and (d) memory of specific facts. From these tests, information about the role of computer graphics for acquisition of specific knowledge categories could be obtained. Where available, aptitude measures, such as General Technical (GT) and Armed Forces Qualifying Test (AFQT) scores, were used to determine the extent of the relationship between aptitude and the type of graphics used.

METHOD

Subjects

Subjects were 90 enlisted personnel (7 females and 83 males) from the Engineering School and the Defense Mapping School, both located at Fort Belvoir, Va. All subjects were high school graduates who were undergoing advanced training at the time of the experiment. Their ages ranged from 17 to 32 years; the mean age was 20.01 years.

Design

Thirty subjects were randomly assigned to each of three groups. All groups were treated identically, except that level of graphics displays during the learning task was varied (either high, medium, or low) between groups.

Lesson Materials

The basic instruction consisted of a linear CAI lesson on the psychophysiology of audition. The lesson comprised four sections: Section 1 dealt with sound wave theory; Section 2 presented the anatomy of the hearing mechanisms of the ear; Section 3 dealt with balance; and Section 4 presented the range of hearing abilities and the deterioration of range with age.

The lesson consisted of 153 frames. Each frame can be defined as a basic instruction unit. Three frames presented introductory material, and Sections 1-4 presented 43, 27, 16, and 64 frames, respectively. After approximately every third frame, students were required to answer either a forced-choice or constructed-answer question based on the immediately preceding material. Students were required to answer the question correctly in order to continue.

Each of the four sections was followed by a review containing 7, 22, 7, and 25 forced-choice questions, respectively. Subjects who failed to answer 85% of the questions in a review correctly were required to repeat the immediately preceding section until they could pass the review. In all other cases, students progressed through the frames in a linear order, but were allowed to repeat the immediately preceding frame if they so chose.

Graphics Levels

Three versions of the lesson on the psychophysiology of audition were developed. Versions were identical except for the level of computer graphics used during the lesson. The low graphics version used only schematic representations (alphanumerics); the medium graphics version used only line drawings; and the high graphics version used animations and line drawings.

Figure 1 shows the low graphics display, which was constructed during a series of lesson frames on the anatomy of the ear. As each part of the ear was discussed in order, from the outer to the inner ear, the corresponding boxed alphanumeric was added to the computer display. Thus, the sequence of connections within the ear was displayed as well as the division into outer, middle, and inner ear sections, but only at a schematic level.

More realistic depictions of the parts of the ear and their interconnections were used for the equivalent medium graphics display, as shown in Figure 2. The high graphics display showed the same line drawing (Figure 2) but in addition, after each part of the ear was added to the display and discussed, provided an animated simulation of the movement of sound waves through the ear. For example, after a discussion of the bones of the middle ear (hammer, anvil, and stirrup),

frame 74

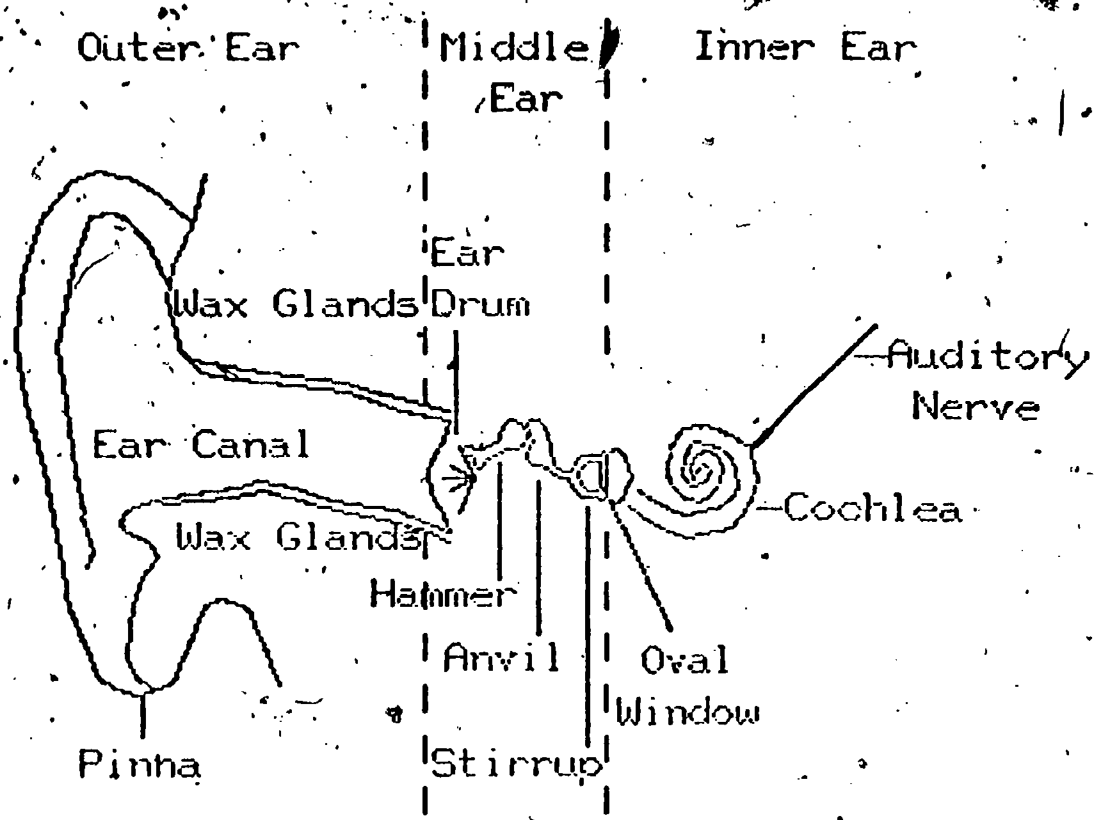
Outer Ear		Middle Ear			Inner Ear	
Pinna	Ear Canal and Wax Glands	Ear Drum	Hammer, Anvil, and Stirrup	Oval Window	Cochlea	Auditory Nerve

AUDITORY NERVE

The auditory nerve leads directly to the brain, which is only about 3/4 inch away. In the brain the message is translated into what you "hear" as "sound".

Figure 1. Example of low graphics level lesson frame.

frame 74



AUDITORY NERVE

The auditory nerve leads directly to the brain, which is only about 3/4 inch away. In the brain the message is translated into what you "hear" as "sound."

Figure 2. Example of medium graphics level lesson frame.

a musical note would move through the ear canal, the ear drum would vibrate, then the middle ear bones would move in sequence.

Attitude Survey

Data on attitudes toward CAI were also collected on line for each subject. The attitude survey (Knerr & Nawrocki, 1978) consisted of a 13-item Likert-scaled pretest and a 37-item posttest. Possible scores on each item ranged from 1 to 5, a score of 1 indicating an unfavorable attitude toward CAI; 3, a neutral attitude; and 5, a very favorable attitude. The posttest employed 13 pretest items, phrased in the past tense, and 24 new items. The internal consistency reliability of each test is reported to be .88 and .93, respectively.

Dependent Measures

Five dependent measures were used: time to complete the lesson and scores on the four content tests: Facts, Terminology, Identification, and Principles. The Facts Test consisted of 20 true/false and multiple-choice items developed to test the subject's knowledge about the qualitative and quantitative modifiers described in the lesson. The Terminology Test consisted of 13 matching items designed to assess the subject's knowledge of the function of the parts of the ear and knowledge of terms used in the lesson. The Identification Test consisted of 14 multiple-choice items which tested the subject's knowledge of the location and/or structure of the parts of the ear. The Principles Test consisted of 21 true/false and multiple-choice items which tested knowledge of the principles and theories discussed in the lesson. Prior to assembling these tests in final form, four raters judged each test item as to the category of knowledge it tested. When disagreements were noted, the item was eliminated.

Apparatus

Except for pre- and postdebriefing sheets, all instruction and data collection took place via one of four PLATO IV terminals located at the Learning Resource Center of the Engineer School, Fort Belvoir, Va. The hardware of the PLATO IV computer-based education system has been described by Stifle (1972). Each terminal consists of an 8.5-inch square plasma display panel and associated typewriter keyboard. Terminals were connected via dedicated telephone lines to a CDC 6500 computer located at the University of Illinois.[1]

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[1] Commercial designations are used for precision of reporting. Their use does not constitute endorsement by the Army Research Institute or the U.S. Army.

Procedures

Upon arrival at the Learning Resource Center, subjects were briefed about the purpose of the experiment. Subjects were randomly assigned to one of the three graphics levels, and then taken to the computer terminals. The experimenter signed subjects onto the PLATO IV system. The subjects first studied a brief CAI lesson on the use of the keyset, then proceeded through the on-line experimental materials in the following order: a biographic information sheet, Attitude Towards CAI Pretest, the CAI lesson on the psychophysiology of audition at the selected graphics level, Facts Test, Terminology Test, Identification Test, Principles Test, and Attitude Towards CAI Posttest.

RESULTS

Performance Measures

The time taken to complete the four sections of the lesson and the four review sections was tallied and combined as a single figure designated lesson completion time. Table 1 presents the mean lesson completion time for each of the three graphics levels. A one-way analysis of variance performed on the lesson completion times indicated that the three graphics groups were not significantly different: $F(2, 87) = .02$.

Table 1

Mean Lesson Completion Time for the Low, Medium, and High Graphics Level

Graphics level	Mean (in minutes)
Low	108.00
Medium	106.82
High	108.86

The number of correct items was tallied for each subject for each of the four content tests. This number was then converted to percent correct. The mean percent correct for each of the three graphics groups for each of the four tests is presented in Table 2.

Table 2

Mean Percent Correct for the Low, Medium, and High Graphics Level Groups on the Four Content Tests

Content test	Graphics level		
	Low	Medium	High
Facts	84.33	83.50	86.00
Terminology	83.59	78.20	83.84
Identification	81.90	82.14	84.28
Principles	70.00	67.93	72.38

The one-way analysis of variance performed on the percent correct data for each of the four content tests resulted in no significant differences among high, medium, and low graphics groups for any of the analyses performed: Facts Test $F(2, 87) = .44$; Terminology Test $F(2, 87) = 1.20$; Identification Test $F(2, 87) = .42$; and Principles Test $F(2, 87) = 1.07$.

Thus, the initial data analyses indicated that the level of computer graphics employed in the lesson was not a significant determinant of success on the content tests or of time spent on the lesson.

Aptitude and Performance

Subject performance was further analyzed with respect to generalized aptitude. GT scores were available for about half the subjects ($n = 51$). Armed Forces Qualification Test (AFQT) scores were also available for about half the subjects ($n = 49$). The subject populations in the GT and AFQT subsamples overlapped considerably and the aptitude scores were correlated with each other, $r(45) = .87$, $p < .01$. Because correlation between aptitude test and performance variables was greater in the GT subsample (range of r values: .49 to .66) than in the AFQT subsample (range of r values: .43 to .63), the results of only one subsample, ~~the~~ GT subsample, will be considered here.

For analysis purposes, the 51 subjects for whom GT scores were available were classified as being high GT scorers (118-140), medium GT scorers (106-116), or low GT scorers (90-104). Cutoff points for the division into groups were determined by first rank-ordering all available GT scores and then dividing the scores into approximate upper, middle, and lower thirds so that high, medium, and low GT scores were about equally represented in the three graphics level

conditions. Table 3 shows the mean GT scores for each of the nine groups.

Table 3

Mean GT Score for Subjects in the Low, Medium, and High Graphics Level Groups Classified as Low, Medium, or High GT Scorers

GT score	Graphics level Low	Graphics level Medium	Graphics level High
Low (90-104)	94.00 (4)	98.5 (6)	101.43 (7)
Medium (106-116)	112.40 (5)	110.33 (7)	111.33 (6)
High (118-140)	131.60 (5)	126.00 (5)	122.17 (6)

Note. The number of scores contributing to each mean is shown in parentheses.

The performance of the GT subsample for each of the five dependent measures was analyzed using two factor analyses of variance with both factors (GT score and graphics level) as between subject factors.

Content Tests. Tables 4 to 7 show the mean scores on each content test as a function of graphics level and GT score category. Consistent with the results for the entire sample, there were no major effects of graphics level in the GT subsample on any of the four content tests: $F(2, 42) = 2.77$ for the Facts Test, .93 for the Terminology Test, 1.10 for the Identification Test, and .29 for the Principles Test.

For the GT subsample, performance on each content test improved with aptitude level: $F(2, 42) = 9.62$ for the Facts Test, 5.34 for the Terminology Test, 12.43 for the Identification Test, and 8.74 for the Principles Test; $p < .01$ in all cases. Graphics level and GT category did not interact: $F(4, 42) = .72$ for the Facts Test, .22 for the Terminology Test, 1.41 for the Identification Test, and 1.10 for the Principles Test.

Table 4

Mean Score on the Facts Test as a Function of Graphics Level and GT Score

GT score	Graphics level: Low	Medium	High
Low	76.25	71.67	84.29
Medium	82.00	82.86	84.17
High	87.00	90.00	95.00

Table 5

Mean Score on the Terminology Test as a Function of Graphics Level and GT Score

GT score	Graphics level: Low	Medium	High
Low	65.38	65.38	78.02
Medium	83.07	74.72	83.33
High	90.76	87.69	92.30

Table 6

Mean Score on the Identification Test as a Function of Graphics Level and GT Score

GT score	Graphics level: Low	Medium	High
Low	62.50	71.42	79.58
Medium	85.71	84.69	84.52
High	87.14	90.00	86.90

Table 7

Mean Score on the Principles Test as a Function of Graphics Level and GT Score

GT score	Graphics level Low	Medium	High
Low	59.52	56.34	68.70
Medium	65.71	69.38	61.90
High	80.95	74.28	78.57

Time. Table 8 shows the mean lesson completion time for each group. The analysis of variance indicated a reliable interaction between graphics level and GT score category, $F(4, 42) = 3.35$, $p < .05$. Scheffe tests at the .05 level indicated that in the high and low graphics level groups low GT scorers took longer to complete the lesson than did medium and high GT scorers, whose time did not differ. GT score category had no effect on lesson completion time for subjects in the medium graphios level groups, however.

Table 8

Mean Completion Time (in Minutes) as a Function of Graphics Level and GT Score

GT score	Graphics level Low	Medium	High
Low	167.45	125.01	140.20
Medium	88.94	119.57	85.23
High	85.48	71.38	78.15

Attitude Toward CAI

The scores for each subject for each item on the pre- and post-test attitude surveys were summed to obtain a total score for each subject for each test. Scores for each item for each test could range

from 1 to 5, a higher score indicating a more favorable attitude toward CAI. The maximum score possible is 65 (13 items x 5) on the pretest and 185 (37 items x 5) on the posttest. Table 9 shows the mean score on both tests for the three graphics level groups. Because pre- and posttest scores were correlated (Pearson Product Moment coefficient = .71, $p < .01$), an analysis of covariance on the posttest scores with pretest scores as the covariate was performed. The analysis of covariance indicated no differences between graphics groups on posttest attitude toward CAI, $F(2, 86) = 1.33$.

Table 9

Mean Pre- and Posttest Attitude Toward CAI Scores for the Low, Medium, and High Graphics Level Groups

Test	Measure	Graphics level: High	Medium	Low
Pretest	$\bar{X}$	46.53	45.83	45.37
Posttest	$\bar{X}$	143.97	137.43	136.43

Knerr (1978) reported additional analyses of the attitude data.

CONCLUSIONS

The results of the present experiment on the comparative instructional effectiveness of three levels of computer graphics can be briefly summarized. Level of computer graphics during learning had no effect on final performance. Subjects receiving simple graphics, such as boxed alphanumerics, combined with a textual CAI presentation performed at the same levels as subjects receiving more realistic visual displays and animations. Although performance on the content tests improved in the GT subsample as a function of aptitude as measured by the GT test, there were no indications of any aptitude x treatment interactions. For the GT subsample, however, time to complete the lesson depended on graphics level and GT score category: Subjects in the medium and high GT categories took less time to complete the lesson than did subjects in the low GT category for the low and high graphics level versions of the lesson. Aptitude had no statistical effect on time to complete the medium level graphics version of the lesson. Practical applications of this finding are unclear, however, particularly because, in all cases, low GT scorers took approximately twice as long to complete the lesson as high aptitude scorers, even for subjects in the medium level graphics group.

The failure to find differential effects for level of computer graphics is consistent with King's (1975) finding. Indeed, these two results suggest that unless the role of graphics in CAI is more clearly delineated, minimal graphics, if any, may be sufficient for effective instruction.

The experimental approach in this and King's (1975) study was to devise a fairly complete and lengthy instructional sequence and to test retention after instruction. In the present study and presumably in the King (1975), study, an attempt was made to incorporate sound instructional practices over and above the use of computer graphics. For example, in the lesson on the psychophysiology of audition, if students failed to meet a stringent criterion on one section of the lesson, they were required to repeat that section before continuing to the next section. Information was given to a student gradually, so that new knowledge could be built on previous knowledge. This strategy was used both between and within lesson sections. As a result, subjects achieved good scores on the final retention tests. On the probable assumption that the subjects as a whole did not have high preexperimental knowledge of the content areas, learning of the material resulted primarily from exposure to the CAI lesson. Any potential effects of graphics during learning may have been masked by the apparent ceiling effects obtained on the retention tests.

It now appears that the experimental approach of designing sound instructional CAI material that uses different levels of computer graphics and of testing for retention after learning is not a fruitful way to investigate the role of graphics in instruction. If graphics do enhance instructional effectiveness in any way, as most educators appear to believe, their influence must be subtle, and more refined techniques would be necessary to discover their instructional role. Perhaps the question which should be asked about the role of graphics in instruction is not, "Are more complex graphics better than less complex graphics?" but rather, "When, where, how, and with whom are graphics to be used?".

Possible approaches to be considered include exploring the role of graphics during the learning process in addition to their role in retention (immediate and more long term) of learned material. Content areas which require interaction with the visual world should also be explored; performance-oriented activities such as vehicular maintenance require visual knowledge to a greater extent than more conceptual areas such as audition or the sine-ratio concept. Correspondingly, tests which require the use of visual information rather than those which place a heavy reliance on text should be used as dependent measures. There is also increasing evidence that individuals differ in their spatial abilities (Kozlowski & Bryant, 1977). It may be that the instructional effectiveness of graphics varies with an individual's spatial aptitude.

CAI's greatest potential appears to be its capability to individualize instruction using interactive techniques. Just as textual material can be presented in an interactive mode, so too can graphics. The applications of interactive graphics to instruction may be a fruitful area of investigation.

As a final note, all three versions of the lesson on the psychophysiology of audition are currently available on the University of Illinois PLATO system. The high graphics level version was selected as part of the Biology PLATO Curriculum. In the 6-month period from 1 January to 1 July 1978, over 250 students at colleges and universities in various locations across the country successfully completed the lesson.

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